The Application of Fuzzy Control in High Accurate Automatic Powder Dosing System

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Abstract—**Have a brief introduction of high accurate powder dosing system ,in order to solve the difficulty in pursuit of high accurate in powder dosing system, researched and analyzed the working character in the last phase –the phase of accurate control, and applied fuzzy control in it to avoided the problem in the construction of the mathematical model. We calculated the inquiring table of the fuzzy rules, for the sake of reducing working time of the computer.**

Keywords-powder dosing ; automatic control; fuzzy control

I. INTRODUCTION

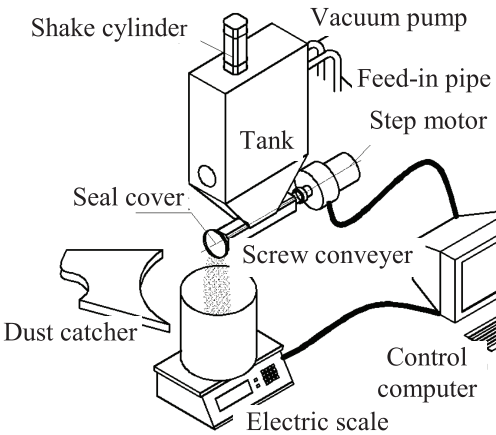

Figure1. Working principles

High accurate powder dosing system is a machine that applied in chemical plant, medicine plant, packinghouse and packaging plant etc. to weight and dosing the grain and powder substance. High accurate, wide scope and high intelligent in weight are the characters of it [1].The working principle was illustrated in Fig.1. The amount of the substance to be weighted was input into the computer at first, the step motor, who driving the screw conveyer to carry substance in the tank into the bullet on the electric scale, was worked by the signal from the computer. The electric scale detected the weight of the powder that had been screwed out and feed it back to control computer, the computer adjust the output signal with the feedback, until the weight of the powder was in the error scope compared with the set amount, the powder dosing process accomplished. Now most researches of automatic dosing system was based on the need of heavy industry, such as mine, concrete plants, iron and steel works etc. most of them worked with PID control arithmetic and the low accurate can't satisfy the precise needed by the high accurate powder dosing system.

II. THE APPLICATION OF FUZZY CONTROL IN HIGH ACCURATE POWDER DOSING SYSTERM

A. Introduce fuzzy control

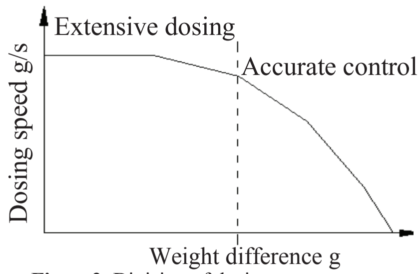

Figure2. Division of dosing process

The whole dosing process can be divided into 2 parts, extensive dosing stage and accurate control stage, is illustrated in Fig.2. The former mostly focus on efficiency but the later, to ensure the high accurate of the system, the powder transportation form is different to the traditional screw conveyor which output powder continuously and imitate wrist shake of manual dosing. It is extremely difficulty to build mathematic model about how the frequency and the range of screw vibration affect dosing speed. It is impossible to receive the high accurate, that the automatic powder dosing system needed, with the traditional PID control method. Fuzzy control is a way of computer control that based on nature language rule and fuzzy logic reasoning. It is one of reasoning control depend on the "fuzzy rules" transformed from operating experience and narrated information, not the accurate mathematic model of the system [2-5]. Undoubtedly it can satisfy the control demand at accurate control stage. The framework of the fuzzy controller in this system is illustrated in Fig.3.

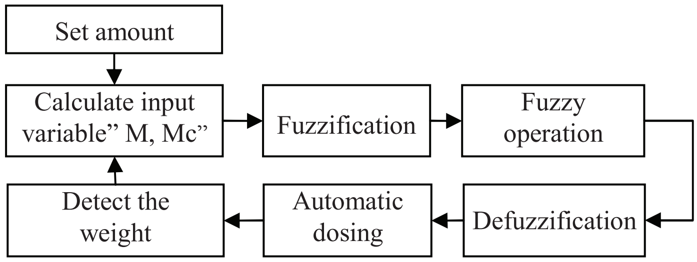

Figure3. Framework of fuzzy controller

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B. Select and fuzzify the input and output

In order to keep accurate of the system we selected dosing speed and weight difference (difference between the outputted and the set amount) as the input variable, the shake frequency and shake range of the step motor as the output variable. As we know the frequency and range of the step motor is based on the frequency and the number of digital pulse to reverse, so we selected the frequency and the number of pulse to reverse as the system output directly for the sake of simplify the system and calculate convenient. Defined variable weight difference is M, dosing speed is Mc, digital pulse frequency is V, the number of pulse to reverse is P. defined their fuzzy sets $\underset{\sim}{A}i = \underset{\sim}{B}i = \underset{\sim}{C}i = \underset{\sim}{D}i$ = {very big(VB), big(BG), middle(MD), small(SM), very small (VS)}(i=1,2,3,4,5), fuzzy fields are X、Y、Z、T. list their membership, under the foundation of expert knowledge and experience in the manual dosing operation, in the table1~table4.

TABLE 1 MEMBERSHIP OF WEIGHT DIFFERENCE

$\mu \underset{\sim}{A}(x)$		X								
		10	**6.5**	**4**	**2.6**	**1.5**	**1.2**	**0.2**	**0.1**	**0.05**
$\underset{\sim}{A}i$	**VB**	1	0.4	0	0	0	0	0	0	0
	BG	0	0.4	1	0.3	0	0	0	0	0
	MD	0	0	0	0.3	1	0.35	0	0	0
	SM	0	0	0	0	0	0.35	1	0.6	0
	VS	0	0	0	0	0	0	0	0.6	1

TABLE 2 MEMBERSHIP OF DOSING SPEED

$\mu \underset{\sim}{B}(y)$		Y								
		1	**0.78**	**0.5**	**0.34**	**0.15**	**0.11**	**0.05**	**0.03**	**0.01**
$\underset{\sim}{B}i$	**VB**	1	0.31	0	0	0	0	0	0	0
	BG	0	0.31	1	0.27	0	0	0	0	0
	MD	0	0	0	0.27	1	0.4	0	0	0
	SM	0	0	0	0	0	0.4	1	0.5	0
	VS	0	0	0	0	0	0	0	0.5	1

TABLE 3 MEMBERSHIP OF PULSE FREQUENCY

$\mu \underset{\sim}{C}(z)$		Z								
		100	**80**	**60**	**45**	**30**	**20**	**10**	**7**	**5**
$\underset{\sim}{C}i$	**VB**	1	0.4	0	0	0	0	0	0	0
	BG	0	0.4	1	0.25	0	0	0	0	0
	MD	0	0	0	0.25	1	0.35	0	0	0
	SM	0	0	0	0	0	0.35	1	0.5	0
	VS	0	0	0	0	0	0	0	0.5	1

TABLE 4 MEMBERSHIP OF THE PULSE NUMBER TO REVERSE

$\mu \underset{\sim}{D}(t)$		T								
		12	**10**	**8**	**7**	**5**	**4**	**2**	**1**	**0**
$\underset{\sim}{D}i$	**VB**	1	0.35	0	0	0	0	0	0	0
	BG	0	0.35	1	0.4	0	0	0	0	0.2
	MD	0	0	0	0.2	1	0.4	0	0	0
	SM	0	0	0	0	0	0.2	1	0.4	0
	VS	0	0	0	0	0	0	0	0	1

C. Fuzzy reasoning

Based on the expert knowledge and the experience of the manual operator we can give fuzzy rules as followed:

(1) if M=VB and MC= VB then V=MD and P=MD;

(2) if M=VB and MC= VS then V=VB and P=VB;

……

(24) if M=VS and MC=MD then V=SM and P=VS;

(25) if M=VS and MC= VS then V=MD and P=VS;

All rules can be summed up and listed in the table5 and table6.

TABLE 5 FUZZY RULES OF THE OUTPUT PULSE FREQUENCY

P		M				
		VB	**BG**	**MD**	**SM**	**VS**
Mc	**VB**	MD	MD	SM	VS	VS
	BG	MD	MD	MD	SM	VS
	MD	BG	BG	MD	SM	SM
	SM	VB	BG	BG	MD	SM
	VS	VB	VB	BG	MD	MD

TABLE 6 FUZZY RULES OF PULSE NUMBER TO REVERSE

V		M				
		VB	**BG**	**MD**	**SM**	**VS**
Mc	**VB**	MD	SM	SM	VS	VS
	BG	MD	MD	MD	VS	VS
	MD	BG	MD	MD	MD	VS
	SM	VB	BG	MD	MD	SM
	VS	VB	VB	BG	MD	SM

The fuzzy relation of P can be deduced from the table5 with the "Mamdani" methods [2-5]:

$$\underset{\sim}{R}_1^V = (\underset{\sim}{A}_1\times\underset{\sim}{C}_3)\cap(\underset{\sim}{B}_1\times\underset{\sim}{C}_3) = \underset{\sim}{R}_{A1}^V\times\underset{\sim}{R}_{B1}^V$$

$$\underset{\sim}{R}_2^V = (\underset{\sim}{A}_1\times\underset{\sim}{C}_1)\cap(\underset{\sim}{B}_5\times\underset{\sim}{C}_1) = \underset{\sim}{R}_{A2}^V\times\underset{\sim}{R}_{B2}^V$$

……

$$\underset{\sim}{R}_{24}^V = (\underset{\sim}{A}_5\times\underset{\sim}{C}_4)\cap(\underset{\sim}{B}_3\times\underset{\sim}{C}_4) = \underset{\sim}{R}_{A24}^V\times\underset{\sim}{R}_{B24}^V$$

$$\underset{\sim}{R}_{25}^V = (\underset{\sim}{A}_5\times\underset{\sim}{C}_3)\cap(\underset{\sim}{B}_5\times\underset{\sim}{C}_3) = \underset{\sim}{R}_{A25}^V\times\underset{\sim}{R}_{B25}^V$$

The fuzzy relation of V can be deduced from the table6 with the "Mamdani" method [2-5]:

$$\underset{\sim}{R}_1^P = (\underset{\sim}{A}_1\times\underset{\sim}{D}_3)\cap(\underset{\sim}{B}_1\times\underset{\sim}{D}_3) = \underset{\sim}{R}_{A1}^P\times\underset{\sim}{R}_{B1}^P$$

$$\underset{\sim}{R}_2^P = (\underset{\sim}{A}_1\times\underset{\sim}{D}_1)\cap(\underset{\sim}{B}_5\times\underset{\sim}{D}_1) = \underset{\sim}{R}_{A2}^P\times\underset{\sim}{R}_{B2}^P$$

……

$$\underset{\sim}{R}_{24}^P = (\underset{\sim}{A}_5\times\underset{\sim}{D}_4)\cap(\underset{\sim}{B}_3\times\underset{\sim}{D}_4) = \underset{\sim}{R}_{A24}^P\times\underset{\sim}{R}_{B24}^P$$

$$\underset{\sim}{R}_{25}^P = (\underset{\sim}{A}_5\times\underset{\sim}{D}_3)\cap(\underset{\sim}{B}_5\times\underset{\sim}{D}_3) = \underset{\sim}{R}_{A25}^P\times\underset{\sim}{R}_{B25}^P$$

In formulary"$\times$,$\cap$"are min operator, means to select the minimum value of the membership[2-5].

For instance:

$$\underset{\sim}{R}^{V}_{A1} = \underset{\sim}{A}_1 \times \underset{\sim}{C}_3 =$$

$$\begin{bmatrix} 1 \\ 0.4 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \circ \begin{bmatrix} 0 & 0 & 0 & 0.25 & 1 & 0.35 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0.25 & 1 & 0.35 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.25 & 0.4 & 0.35 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 00 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\underset{\sim}{R}^{V}_{B1} = \underset{\sim}{B}_1 \times \underset{\sim}{C}_3 =$$

$$\begin{bmatrix} 1 \\ 0.31 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \circ \begin{bmatrix} 0 & 0 & 0 & 0.25 & 1 & 0.35 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0.25 & 1 & 0.35 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.25 & 0.31 & 0.31 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 00 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Obviously $\underset{\sim}{R}^{V}_{B1} \in \underset{\sim}{R}^{V}_{A1}$,

so:

$$\underset{\sim}{R}^{V}_{1} = \underset{\sim}{R}^{V}_{A1} \bigcap \underset{\sim}{R}^{V}_{B1} = \underset{\sim}{R}^{V}_{B1} = \begin{bmatrix} 0 & 0 & 0 & 0.25 & 1 & 0.35 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.25 & 0.31 & 0.31 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

In the same way ,we can get $\underset{\sim}{R}^{V}_{1}$ 、 $\underset{\sim}{R}^{P}_{1}$ ...... $\underset{\sim}{R}^{V}_{25}$ 、 $\underset{\sim}{R}^{P}_{25}$ 。

So the general fuzzy relationship can be deduced:

$$\underset{\sim}{R}^{V} = \bigcup_{i=1}^{25} \underset{\sim}{R}^{V}_{i}$$

$$\underset{\sim}{R}^{P} = \bigcup_{i=1}^{25} \underset{\sim}{R}^{P}_{i}$$

In formulary "$\bigcup$"are max operator, means to select the maximum of membership [2-5].

We can get the fuzzy output, the pulse frequency and pulse number to reverse, from the fuzzy implications:

$$\underset{\sim}{C}^{*} = (\underset{\sim}{A}^{*} \bigcap \underset{\sim}{B}^{*}) \circ R^{V}$$

$$\underset{\sim}{D}^{*} = (\underset{\sim}{A}^{*} \bigcap \underset{\sim}{B}^{*}) \circ R^{P}$$

D. Defuzzification

The ways of defuzzification are not sole, due to the severe ununiformity division of the fuzzy intervals, on the purpose of keeping accurate we used the way SOM to defuzzify, when there are several dots have maximum membership select the minimum value among the maximum membership dots as the defuzzification value. In order to reduce time in computer calculating, we calculated the discrete maximum membership of P and V and list them in the table 7 and table 8.

TABLE 7 QUERY TABLE OF PULSE FREQUENCY

P		M								
		10	***6.5***	***4***	***2.6***	***1.5***	***1.2***	***0.2***	***0.1***	***0.05***
Mc	***1***	33	33	33	29	15	15	6	6	5
	0.78	34	34	34	30	30	30	15	15	7
	0.5	44	46	44	46	33	32	15	14	13
	0.34	53	54	54	51	34	32	15	15	15
	0.15	65	66	63	51	47	46	26	26	15
	0.11	69	67	64	52	52	51	29	27	16
	0.05	87	67	63	64	63	58	31	26	15
	0.03	87	69	68	69	64	57	31	30	29
	0	87	85	87	69	64	58	33	33	33

TABLE 8 QUERY TABLE OF PULSE NUMBER TO REVERSE

V		M								
		10	***6.5***	***4***	***2.6***	***1.5***	***1.2***	***0.2***	***0.1***	***0.05***
Mc	***1***	5	4	2	2	2	2	1	1	1
	0.78	5	4	4	4	4	4	1	1	1
	0.5	6	6	5	5	5	4	3	3	1
	0.34	7	6	5	5	5	5	4	4	2
	0.15	8	7	6	6	5	5	4	3	2
	0.11	9	7	7	7	5	5	4	3	2
	0.05	11	9	8	7	5	7	4	3	2
	0.03	11	9	9	7	7	7	4	4	2
	0	11	11	11	9	8	7	4	3	2

III. THE REALIZATION OF FUZZY CONTROL

The automatic dosing system is controlled by industrial personal computer (IPC), the control process is programmed with Visal c++, the whole processes is illustrated in Fig.4:

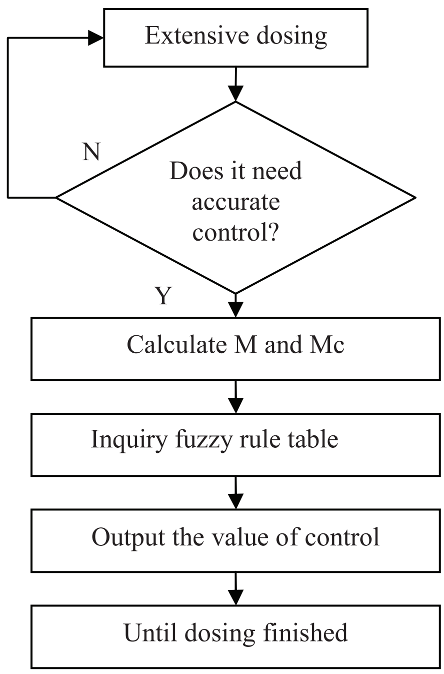

Figure4. Flow chart of fuzzy control

IV. THE END

Fuzzy control successfully solved the problem that arithmetic model can't be established. There have 1000 times dosing experiment before and after applied fuzzy control separately. The experiment data is listed in table 9.

TABLE 9 THE CONTRAST BEFORE AND AFTER APPLIED FUZZY CONTROL

	Experiment times	Accurate demand	Inaccuracy times	Biggest error	Accurate control time
No fuzzy control	1000	±0.1	26	0.46g	43.1s
Fuzzy control	1000	±0.05	3	0.08g	28.7s

The experiment data tell us that fuzzy control can obviously enhanced the accurate and the efficiency of the system.

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